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Barstovian (middle Miocene) Land Mammals from the Carmel Church Quarry, Caroline County, Virginia

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Barstovian (middle Miocene) Land Mammals from the Carmel Church Quarry, Caroline County, Virginia

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ABSTRACT

Excavation of marine sediments of the Calvert Formation at the Carmel Church Quarry has resulted in the collection of remains of several land mammals. These include the first reports from the upper Calvert Formation of the family Dromomerycidae and of the equid *Calippus* cf. *regulus* as well as the tayassuid "*Prosthennops*" *xiphidonticus* and a tapirid. The presence of *Calippus* cf. *regulus* and *"Prosthennops" xiphidonticus* indicate a late Barstovian age for this deposit, which is consistent with previous assessments based on diatoms.

Keywords: Miocene, Calvert Formation

INTRODUCTION

The middle Miocene Calvert Formation is extensively exposed in erosional cliffs along the Chesapeake Bay and various rivers in the Coastal Plain of Virginia and Maryland. While best known for its extensive marine fauna, the Calvert Formation has also produced significant remains of fossil land mammals. Cope (1868) first published a report of a land mammal (a peccary tooth) from the Calvert (see Woodburne, 1969, Wright & Eshelman, 1987, and Dooley, 2003 for discussion of this specimen). Further reports and summaries of Calvert land mammals include Gazin & Collins (1950), Woodburne (1969), Whitmore, (1971, 1984), Tedford & Hunter (1984), and Wright & Eshelman (1987). However, the number of published studies on Calvert land mammals belies the relative rarity of specimens. Only the Pollack Farm site in Delaware has produced large numbers of land mammals (Emry & Eshelman, 1998). The Pollack Farm specimens all come from the lower Calvert Formation (some authors assign these deposits to the equivalent Kirkwood Formation—see Ward, 1998). In contrast, the upper part of the Calvert Formation has produced only a few dozen land mammal specimens in approximately 150 years of collecting.

The exposed Tertiary section of the Carmel Church Quarry in Caroline County, Virginia includes one bed of Calvert Formation sediments, approximately 0.5-1.0 meters thick (Dooley et al, 2004). Carmel Church has produced abundant remains of marine vertebrates including cetaceans, sirenians, phocids, marine reptiles, chondrichthians, and osteichthians (Dooley & Fraser, 2005). Carmel Church is the westernmost known exposure of the Calvert Formation, and is therefore possibly the nearest to the paleoshoreline as well. This may account for the unusual abundance of terrestrial mammals and plants relative to other localities in the upper part of the Calvert Formation.

METHODS

The Carmel Church specimens were compared with published illustrations of comparable specimens, as well as specimens from other localities stored at the Florida Museum of Natural History, the American Museum of Natural History, and the United States National Museum. Anatomical terminology and measurements for equids follows Hulbert (1988); for tayassuids, Wright & Eshelman (1987). North American land mammal biostratigraphy follows Carrasco et al., 2005.

Anatomical abbreviations: c, canine; d, deciduous tooth; I, incisor; m, molar; p, premolar. Upper teeth are designated by uppercase abbreviations, lower teeth by lowercase abbreviations.

Institutional abbreviations: AMNH, American Museum of Natural History, New York, New York; UF, Florida Museum of Natural History, Gainesville, Florida; FAM, Frick Collection of Fossil Vertebrates, housed at AMNH, New York, New York; TMM, Texas Memorial Museum, Austin, TX; USNM, United States National Museum, Washington, DC; VMNH, Virginia Museum of Natural History, Martinsville, Virginia.

SYSTEMATIC PALEONTOLOGY

Order PERISSODACTYLA Owen, 1848
Family EQUIDAE Gray, 1821
Genus CALIPPUS Matthew & Stirton, 1930
Calippus cf. *regulus* Johnston, 1937

Referred specimen: VMNH 3529, partial maxillae with portions of ten teeth, including R DP3-4, R M1-2, L DP2-4, L M1-2, and non-erupted R P3. Collected by Brett Dooley, July 2001 (Figure 1).

This specimen was originally reported as *Merychippus* sp. (Dooley & Fraser, 2005). It includes maxillary fragments with ten preserved teeth, including worn deciduous premolars, slightly worn first molars, and unworn, non-erupted or partially erupted second molars. The partial non-erupted right P3 is *in situ* above DP3. In the

deciduous premolars, the elongate protocone is connected to the protoselene. The fossettes are simple, and there is no pli caballin. The hypoconal groove is open in DP2 and forms a lake in DP3. The parastyle and mesostyle are fairly prominent. The fossettes are simple, with a single small pli postfossette in DP4.

Tooth eruption patterns indicate that VMNH 3529 was a young juvenile. In *Equus*, the first permanent tooth to erupt is M1, at an age of approximately one year. In VMNH 3529, M1 exhibits only very slight wear, while M2 was unworn and had probably not erupted, and M3 had not begun to form.

The Carmel Church specimen is very similar in both size and overall morphology to *Calippus regulus* and *Calippus proplacidus*. Compared to *C. proplacidus*, *C. regulus* has molar crowns that are shorter anteroposteriorly but higher, and with simpler fossettes. Overall, VMNH 3529 is more similar to specimens referred to *C. regulus*. The DP enamel pattern of VMNH 3529 is similar to that of TMM 30896-173 (*C. regulus*) as figured by Quinn (1955); these specimens appear to represent comparable stages of growth and wear. Differences include the presence of a hypoconal lake in DP2-3 of TMM 30896-173, but in DP4 of VMNH 3529. The deciduous upper premolars of FAM 118206, also referred to *C. regulus*, lack hypoconal lakes. The crown length of M1 (approximately 16 mm) is a little larger than typical for *C. regulus*, and more typical for *C. proplacidus,* based on the data from Hulbert (1988). However, this length does fall within the range of preserved *C. regulus* specimens (for example, USNM 42431, AMNH 118230). The M1 crown height of VMNH 3529 falls within the range for *C. regulus*, and is greater than for *Calippus proplacidus* (Hulbert, 1988).

Calippus regulus has been reported from the late Barstovian to middle Clarendonian of the Great Plains and Texas Gulf Coast (Hulbert, 1988; Forsten, 1975; Quinn, 1955). *Calippus proplacidus* has been reported from the late Barstovian of Colorado, Nebraska, Texas, and Florida (Hulbert, 1988).

TABLE 1. MEASUREMENTS OF TEETH OF VMNH 3529.

Anteroposterior length of left DP3	18.5 mm
Anteroposterior length of right DP3	18.4 mm
Anteroposterior length of left DP4	19.1 mm
Anteroposterior length of right DP4	18.5 mm
Anteroposterior length of left M1	16.0 mm
Unworn crown height of left M1	45.2 mm
Anteroposterior length of right M1	16.4 mm
Unworn crown height of right M1	44.1 mm
Anteroposterior length of left M2	16.0 mm

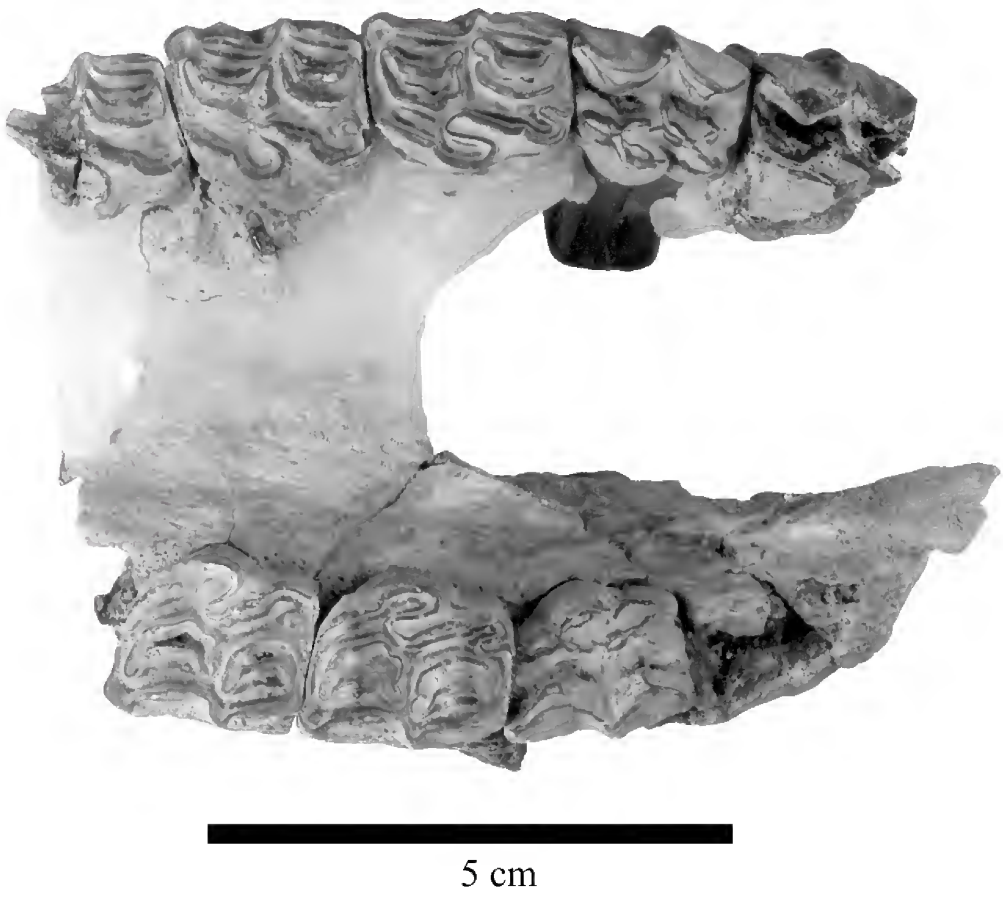

Figure 1. VMNH 3529, *Calippus* cf. *regulus*, partial maxillae with teeth, occlusal view. Anterior is to the left. Scale = 5 cm.

Family EQUIDAE Gray, 1821
Genus indeterminate

Referred specimen: VMNH 1802, isolated right third metatarsal. Collected by Bryce Harrison, July 2003 (Figure 2).

VMNH 1802 is a nearly complete equid right metatarsal III. This specimen is smaller than FAM 69511, a referred specimen of *Merychippus coloradense*, but is considerably longer and more gracile than an uncatalogued metatarsal in the FAM collection, which is associated with material referred to *Calippus regulus*. The length of the FAM specimen is only 84% that of VMNH 1802, but the width at the distal end is 109% of VMNH 1802. The proximal articular surface in VMNH 1802 is flatter than in the FAM specimen. The different proportions and shape of this metatarsal compared to the FAM specimen suggests the possibility of a second genus of equid at Carmel Church.

Figure 2. VMNH 1802, Equidae, right metatarsal. A. anterior, B. posterior, C. medial, D. lateral. Scale = 5 cm.

Table 2. Measurements of equid right metatarsal, VMNH 1802.

Length	165 mm
Width at proximal end	23 mm
Length at proximal end	20 mm
Width at distal end	19 mm
Length at distal end	15 mm

Family TAPIRIDAE Gray, 1821
Genus indeterminate

Referred specimens: VMNH 1803, partial right deciduous lower premolar. Collected by L. W. Ward, November 1991 (Figure 3). VMNH 1804, left third metacarpal. Collected by C. R. Harrison, March 2001 (Figure 4).

The tooth fragment is the posterior cusp of a deciduous lower left premolar. This fragment is smaller than the permanent premolars and molars in *Tapirus johnsoni* (FAM 37302). Compared to FAM 37302, the Carmel Church specimen has a more squared-off profile in occlusal view. The broken edge of the anterior cusp suggests that this cusp was narrower than in FAM 37302.

The left third metacarpal is similar in shape to the same element from *Tapirus webbi* (UF 26474). The Carmel Church specimen is smaller than *T. webbi*, with a metatarsal length about 85% of that in UF 26474.

Table 3. Measurements of tapirid premolar, VMNH 1803, and left third metacarpal, VMNH 1804.

Height of crown VMNH 1803	15 mm
Width of crown VMNH 1803	16 mm
Length VMNH 1804	119 mm
Width at proximal end VMNH 1804	26.5 mm
Length at proximal end VMNH 1804	22 mm
Width at distal end VMNH 1804	27 mm
Length at distal end VMNH 1804	21 mm

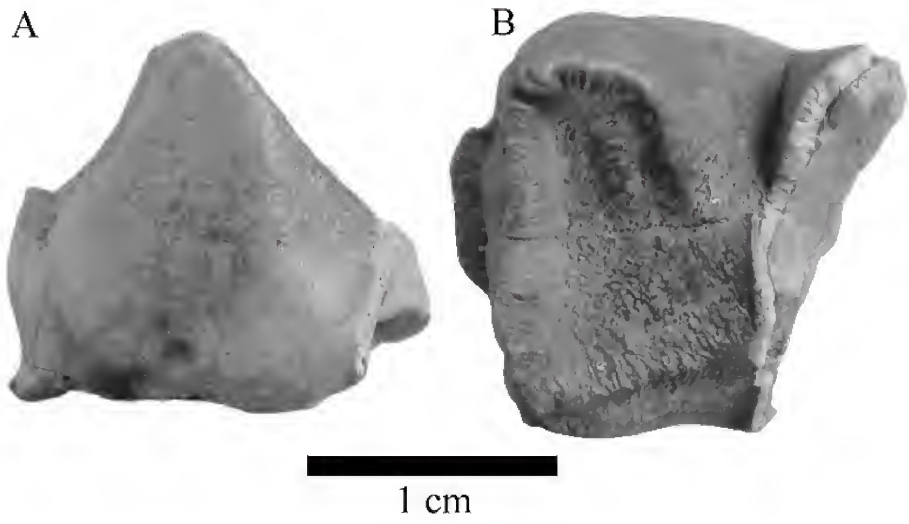

Figure 3. VMNH 1803, Tapiridae, right deciduous lower premolar. A. lateral, B. occlusal. Anterior is to the right. Scale = 1 cm.

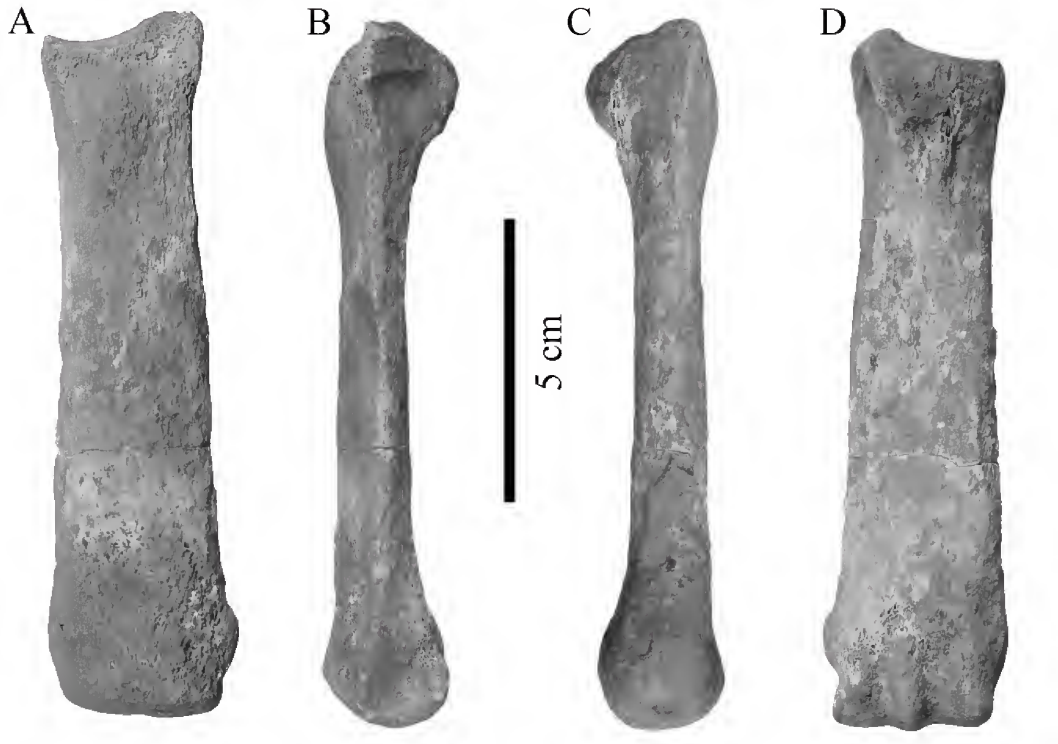

Figure 4. VMNH 1804, Tapiridae, left third metacarpal. A. anterior, B. medial, C. lateral, D. posterior. Scale = 5 cm.

Order ARTIODACTYLA Owen, 1848
Family TAYASSUIDAE Palmer, 1897
Genus "PROSTHENNOPS" Wright & Eshelman, 1987
"Prosthennops" xiphidonticus (Barbour, 1925)

Referred specimens: VMNH 1800, partial mandible including partial left and right canines, right p3, partial right m3, and left p3-m1. Collected by S. Whitehurst, November 2002 (Figure 5A-D). Tenative referrals: VMNH 1805, left second metatarsal. Collected by A. C. Dooley, Jr. and P. R. Murdoch, March 2004 (Figure 5E-H). VMNH1806, upper right canine. Collected by J. Sarao, June 2005 (Figure 5I-J).

The partial mandible includes portions of both dentaries with both canines, rp3, a portion of rm3, and lp3-m1 *in situ*. Root fragments of li1-2 and ri1 are also present.

The morphology of p3 matches closely p3 of USNM 25795, a specimen of "*Prosthennops*" *xiphidonticus* from the Calvert Formation in Westmoreland County, Virginia (Wright & Eshelman, 1987), although VMNH 1800 shows more wear than the Westmoreland specimen. In its lack of a distinct metaconid, VMNH 1800 is similar to "*P.*" *xiphidonticus* and distinct from the slightly younger "*P.*" *niobrarensis* (Wright, 1998), which is known from the Choptank Formation (Wright & Eshelman, 1987).

In USNM 20518, a specimen of "*P.*" *xiphidonticus* from Calvert County, Maryland, the metaconid of p4 has a posterolabial process (Wright & Eshelman, 1987); this process is also present in p4 of VMNH 1800, and also occurs in "*P.*" *niobrarensis* (Wright & Eshelman, 1987). Interestingly, in both VMNH 1800 and USNM 20518, m1 seems to show more extensive wear than the other lower teeth.

Only the base of the right canine is preserved. The complete but poorly preserved left canine shows evidence of wear both apically and along the posterior margin.

In spite of its adult dentition, VMNH 1800 is slightly smaller than either USNM 25795 or USNM 20518 (p3 crown length of 10.8 mm vs. 11.3 mm), and considerably smaller than "*P.*" *niobrarensis* specimens from the Choptank Formation (such as USNM 243740 with a p3 crown length of 13.5 mm). During the Miocene, the trend in peccaries is toward larger size (Wright & Eshelman, 1987).

Table 4. Measurements of teeth of VMNH 1800. All measurements in mm.

	l c	l p3	r p3	r p4	r m1	l m3
Crown height	25.6	7.6	6.7	8.5	6.7	7.7
Maximum length of crown	10.3	10.8	10.3	12.3	13.6	--
Maximum width of crown	9.4	5.8	6.0	8.7	10.5	11.5

The upper right canine (VMNH 1806) is recurved with the crown making up a little less than half of the length of the tooth. There is a prominent wear facet along the anterior margin, as is typical in peccaries. The posterior margin has a sharp, non-serrate cutting edge. A cingulum is present anteriorly on both the lingual and labial surfaces; the cingulum does not extend to the posterior half of the crown. There are a series of fine enamel longitudinal ridges covering the basal 3/4 of the crown.

Table 5. Measurements of tayassuid canine VMNH 1806.

Overall height	74 mm
Crown height	31 mm
Length of crown at base	13 mm
Width of crown at base	7 mm

The left second metatarsal has a flattened lateral surface, which in life contacted the third metatarsal. This surface extends from the proximal end of the element to a point 14 mm proximal to the distal end. While this specimen is not diagnostic, its size is consistent with other Calvert Formation *"Prosthennops"* material.

Table 6. Measurements of tayassuid left second metatarsal, VMNH 1805.

Length	100 mm
Width at proximal end	12 mm
Length at proximal end	20 mm
Width at distal end	13 mm
Length at distal end	15 mm

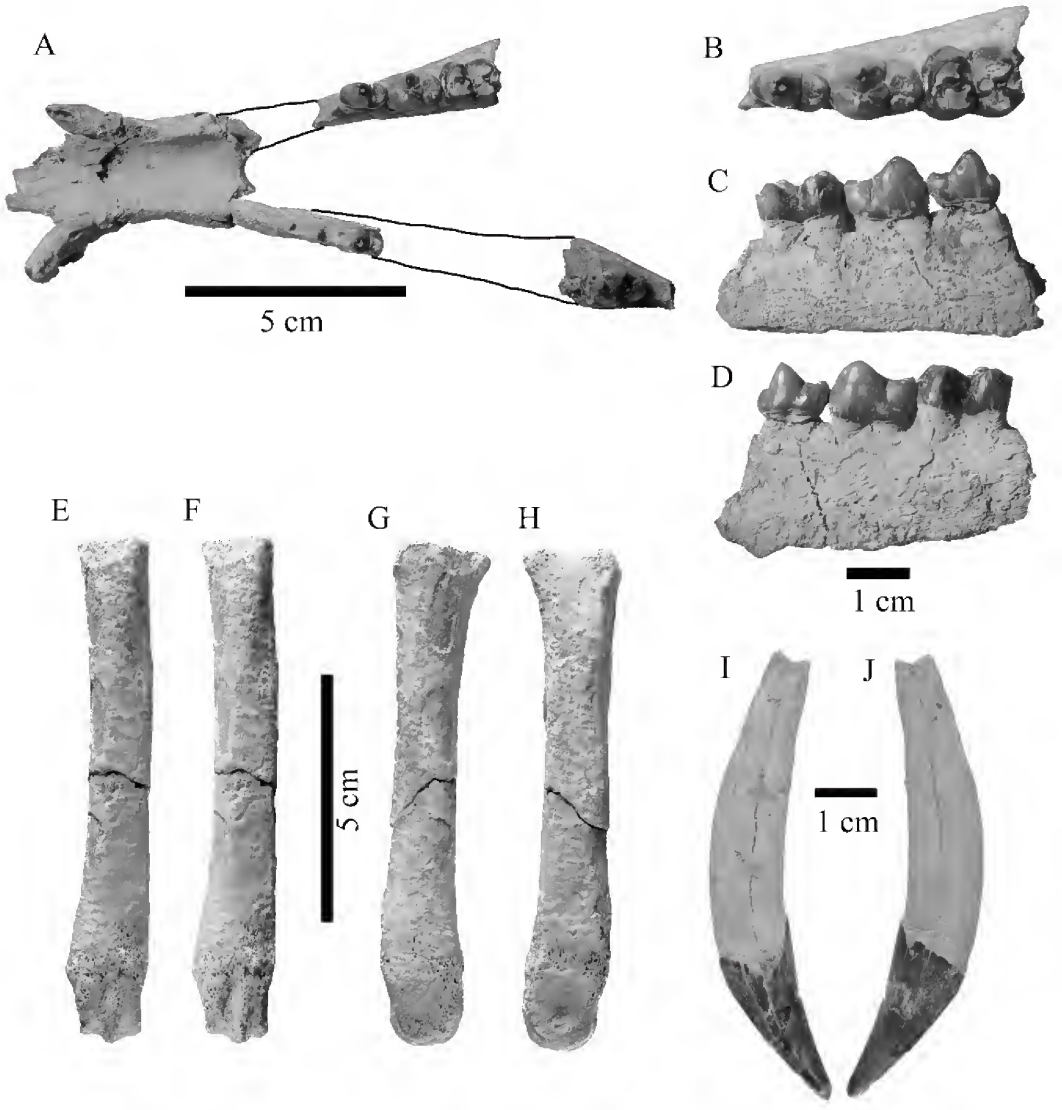

Figure 5. "*Prosthennops*" *xiphidonticus* A-D, VMNH 1800, partial mandible. A, mandible in dorsal view. Right dentary fragment with p3-m1 in B, occlusal view, C, lateral view, and D, medial view. E-F VMNH 1805, left second metatarsal. E, anterior view, F, posterior view, G, lateral view, and H, medial view. I-J, VMNH 1806, upper right canine. I, medial view, and J, lateral view.

Family DROMOMERYCIDAE *sensu* Janis and Manning, 1998
Genus indeterminate.

Referred specimen: VMNH 1778, associated hindlimb material including the distal end of the left femur, both tibiae, and the proximal part of the left metatarsal. Femur and tibiae collected by Greg McKee, March 1999; metatarsal collected by Annabel Goodridge, April 2006 (Figures 6, 7).

These remains were originally reported as a possible protoceratid (Fraser & Dooley, 2000). Even though these remains were collected seven years apart, they were collected from the same excavation pit within a few centimeters of each other. The physical proximity, consistent size and morphology, and similar preservation of these elements indicate that all the remains are likely to be from a single individual.

Only the distal half of the left femur is preserved. The preserved portion is slender and curved. The lateral supercondyloid crest is low, with a deep adjacent supercondylar fossa. There is a small horizontal shelf of bone at the base of the lateral epicondyle that projects laterally at the distal end of the supercondylar fossa. The vascular groove along the posteromedial surface is prominent. There is a deep intercondylar fossa.

The tibiae are long and slender. The lateral condyle and the lateral tubercle of the spine are larger than their medial counterparts. In proximal view the articular surface of the lateral condyle is trapezoidal in outline, while the medial condyle is more triangular. The intercondyloid fossa is rather wide. The tuberosity of the tibial crest has a low transverse ridge separating shallow anterior and posterior depressions. There is a small nutrient foramen on the posterolateral margin about one-third of the shaft length distal to the proximal end of the shaft. There is a single prominent muscular line running along the proximal half of the posterior side of the tibia. There is a moderately pronounced lateral malleolus, with a distinct fossa for articulating with the distal end of the fibula. The proximal part of each fibula is preserved fused to its corresponding tibia as a short ventrally-oriented projection.

The distal part of the left metatarsal is preserved. This is relatively flat on the articular surface, and with a deep groove (between digits III and IV) along the posterior surface, and a shallower groove on the anterior surface. As is typical in dromomerycids, digit III is larger than digit IV, giving the metatarsal an assymetrical appearance.

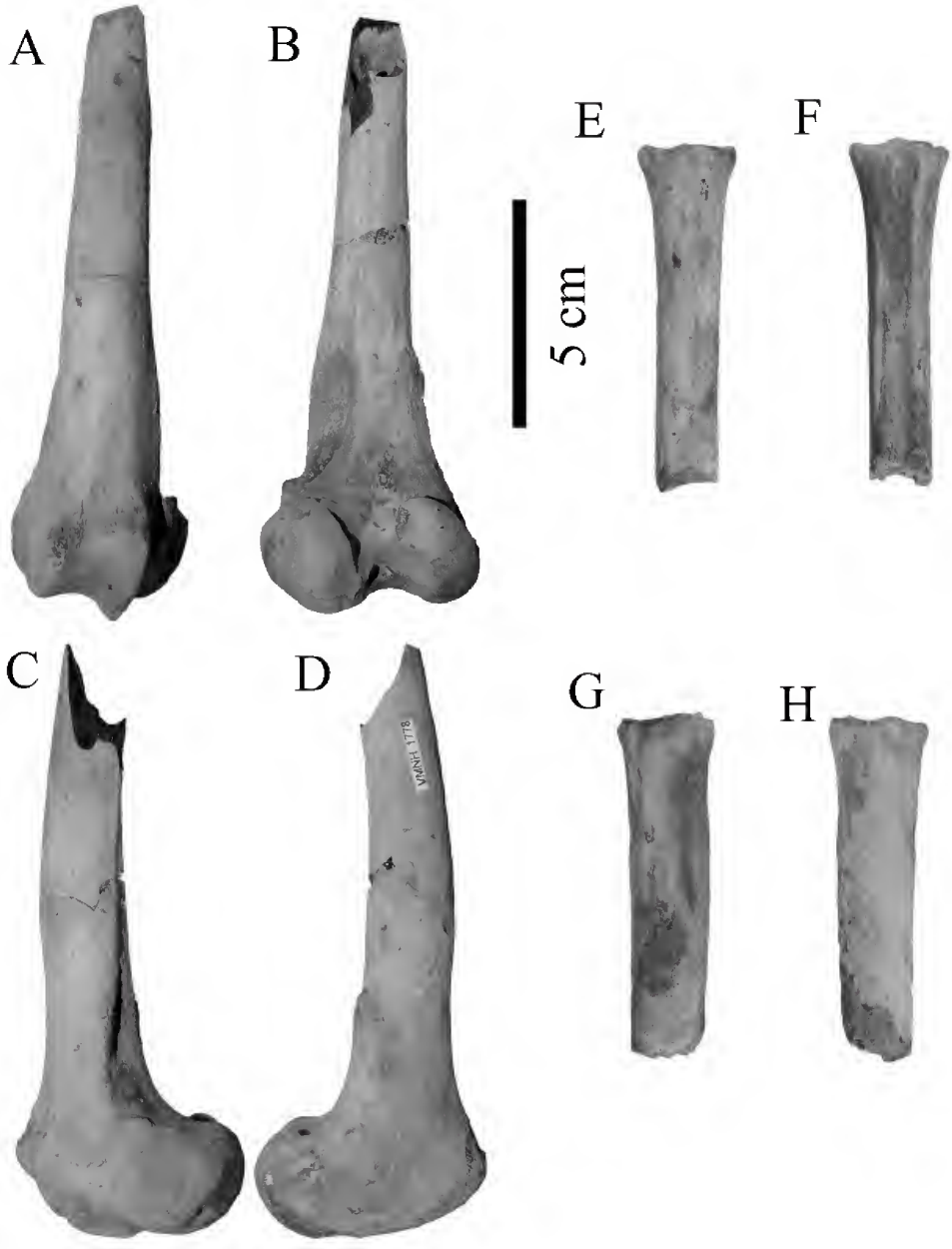

Figure 6. VMNH 1778, Dromomerycidae. A-D, left femur. A, anterior, B, posterior, C, lateral, D, medial. E-H, left metatarsal. E, anterior, F, posterior, G, lateral, H, medial. Scale = 5 cm.

Figure 7. VMNH 1778, Dromomerycidae. A-D, left tibia. A, anterior, B, posterior, C, lateral, D, medial. E-H, right tibia. E, anterior, F, posterior, G, lateral, H, medial. Scale = 5 cm.

Both the femur and the right tibia have fine parallel scratches presumably associated with scavenging, most likely by sharks or fish. Many of the marine fossils in the Carmel Church deposits show similar scratches.

In shape, the Carmel Church specimens closely resemble specimens of *Cranioceras* sp. (AMNH 54636, AMNH 54637), *Procranioceros skinneri* (AMNH 31929), and *Pediomeryx* sp. (UF 69946); however, the Carmel Church specimens are only about 75% as large as these specimens. The tibia length of VMNH 1778 is comparable to *Cranioceras granti* of Frick (1937).The questionable diagnostic usefulness of hindlimb material, combined with the poor state of dromomerycid taxonomy (Janis & Manning, 1998; Prothero & Liter, 2006) makes a generic identification impossible.

TABLE 7. MEASUREMENTS OF DROMOMERYCID HIND LIMB ELEMENTS, VMNH 1778.

Width of femur across condyles	45 mm
Maximum length of femur at distal end	52 mm
Length of left tibia	211 mm
Length of right tibia	214 mm
Maximum width of left tibia at proximal end	46 mm
Maximum width of right tibia at proximal end	48 mm
Maximum width of left tibia at distal end	29 mm
Maximum width of right tibia at distal end	29 mm
Minimum diameter of shaft of left tibia	14 mm
Minimum diameter of shaft of left tibia	15 mm
Maximum width of left metatarsal at proximal end	22 mm

BIOSTRATIGRAPHIC SIGNIFICANCE

As noted by Tedford & Hunter (1984) and Wright & Eshelman (1987), the presence of land mammals in a marine deposit such as the Calvert Formation allows for the correlation of biostratigraphic zones across terrestrial and marine realms. Gazin & Collins (1950) and Wright & Eschelman (1987) determined that the Plum Point Member of the Calvert Formation correlated with the Barstovian Land Mammal Age.

Previous studies on Carmel Church diatoms by Andrews (1985) indicates that the Calvert Formation at this locality falls with East Coast Diatom Zone (ECDZ) 6 of Andrews (1988). Two of the land mammals preserved at Carmel Church are useful for biostratigraphic correlation: "*Prosthennops*" *xiphidonticus* and *Calippus* cf. *regulus*. "*P.*" *xiphidonticus* is known throughout the Barstovian

(Wright, 1998), while *C. regulus* is known from the late Barstovian through the Clarendonian (Hulbert, 1988; Forsten, 1975; Quinn, 1955). This suggests a late Barstovian age for the Calvert Formation at Carmel Church, with an age range of 15.9-12.5 Ma (Carrasco et al., 2005).

In the Chesapeake Group, "*P.*" *xiphidonticus* has only been reported from Bed 14 of the Calvert Formation (Wright & Eshelman, 1987). Older units in the Calvert produce other tayassuids." Tayassuid sp. A" of Wright & Eshelman (1987) is found in the Fairhaven Member of the Calvert, while the lower part of the Plum Point Member (Beds 4-12) produces *Cynorca proterva*. Likewise, "*P.*" *niobrarensis* is found in the next higher stratigraphic unit, Bed 17 of the Choptank Formation (Wright & Eshelman, 1987). This indicates that the Calvert bed exposed at Carmel Church correlates with Bed 14 in Westmoreland County, Virginia and Calvert County, Maryland.

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REFERENCES CITED

Andrews, G. W. 1985. Unpublished report on diatoms of the Carmel Church Quarry. United States Geological Survey E&R Report, 1p.

Andrews, G. W. 1988. A revised marine diatom zonation for Miocene strata of the southeastern United States. U. S. Geological Survey Professional Paper 1481, 1-29.Cope, E. D., 1868.

Barbour, E. H., 1925. *Prosthennops xiphidonticus* sp. nov., a new fossil peccary from Nebraska. Bulletin of the University of Nebraska State Museum 1:25-32.

Carrasco, M. A., B. P. Kraatz, & A. D. Barnosky, 2005. Miocene Mammal Mapping Project (MIOMAP). University of California Museum of Paleontology, http://www.ucmp.berkeley.edu/miomap

Dooley, A. C. Jr., 2003. A review of the eastern North American Squalodontidae (Mammalia: Cetacea). Jeffersoniana 11:1-26.

Dooley, A. C. Jr. & N. C. Fraser, 2005. A revised faunal list for the Carmel Church Quarry, Caroline County, Virginia. Journal of Vertebrate Paleontology 25(Suppl. To 3):52A.

Dooley, A. C. Jr., N. C. Fraser, & Z.-X. Luo, 2004. The earliest known member of the rorqual-gray whale clade (Mammalia, Cetacea). Journal of Vertebrate Paleontology 24(2):453-463.

Emry, R. J. & R. E. Eshelman, 1998.The early Hemingfordian (early Miocene) Pollack Farm Local Fauna: First Tertiary land mammals described from Delaware, *in* R. N. Benson, ed., Geology and Paleontology of the lower Miocene Pollack Farm Fossil Site. Delaware Geological Survey Special Publication No. 21:153-173.

Forsten, A., 1975. The fossils horses of the Texas Gulf Coastal Plain: A revision. Texas Memorial Museum Pearce-Sellards Series 22:1-86.

Fraser, N. C., & A. C. Dooley Jr., 2000. A diverse marine vertebrate assemblage from a locality in the Calvert Formation of Virginia. Journal of Vertebrate Paleontology 20(Suppl. to 3):42A.

Frick, C., 1937. Horned ruminants of North America. Bulletin of the American Museum of Natural History 59:xxviii+669 p.

Gazin, C. L. & R. L. Collins, 1950. Remains of land mammals from the Miocene of the Chesapeake Bay Region. Smithsonian Miscellaneous Collections, 116 (2):1-21.

Gray, J. E., 1821. On the natural arrangement of vertebrose animals. London Medical Repository and Review 15:296-310.

Hulbert, R. C. Jr., 1988. Calippus and Protohippus (Mammalia, Perissodactyla, Equidae) from the Miocene (Barstovian-early Hemphillian) of the Gulf Coastal Plain. Bulletin of the Florida State Museum, Biological Sciences 32(3):221-340.

Hulbert, R. C. Jr. 2001. The Fossil Vertebrates of Florida. University Press of Florida. Gainesville, FL. 350pp.

Janis, C. M. & E. Manning, 1998. Dromomerycidae, *in* C. M. Janis, K. M. Scott, and L. J. Jacobs, eds. Evolution of Tertiary Mammals in North America. Cambridge University Press, Cambridge. p. 477-490.

Johnston, C. S., 1937. Calippus regulus from the Clarendon beds of Donley County, Texas. American Midland Naturalist 18:905-907.

Matthew, W. D. & R. A. Stirton, 1930. Equidae from the Pliocene of Texas. Bulletin of the Department of Geological Sciences, University of California 9:49-58.

Owen, R., 1848. Description of teeth and portions of jaws of two extinct anthracotheroid quadrupeds…with an attempt to develop Cuvier's idea of the classification of pachyderms by the number of their toes. Quarterly Journal of the Geological Society of London 4:104-141.

Palmer, T. S., 1897. Notes on the nomenclature of four genera of tropical American mammals. Proceedings of the Biological Society of Washington 11:173.

Prothero, D. & M. Liter, 2006. The effects of oversplit taxonomy on diversity curves: the dromomerycid data base. Journal of Vertebrate Paleontology 26(Suppl. To 3):112A-113A.

Quinn, J. H., 1955. Miocene Equidae of the Texas Gulf Coastal Plain. Bureau of Economic Geology, University of Texas Publication No. 5516:1-102.

Tedford, R. H. & M. E. Hunter, 1984. Miocene marine-nonmarine correlations, Atlantic and Gulf Coastal Plains, North America. Palaeogeography, Palaeoclimatology, Palaeoecology 47:129-151.

Ward, L. W. 1992. Molluscan Biostratigraphy of the Miocene, middle Atlantic coastal plain of North America. Virginia Museum of Natural History, Memoir Number 2. 159pp.

Ward, L. W., 1998. Mollusks from the lower Miocene Pollack Farm Site, Kent County, Delaware: a preliminary analysis, *in* R. N. Benson, ed., Geology and Paleontology of the lower Miocene Pollack Farm Fossil Site. Delaware Geological Survey Special Publication No. 21:59-131.

Whitmore, F. C. Jr., 1971. Vertebrate biofacies and paleoenvironments, in R. E. Gernant, T. G. Gibson, and F. C. Whitmore, Jr., eds. Environmental history of Maryland Miocene. Maryland Geological Survey Guidebook No. 3, p. 31-43.

Whitmore, F. C. Jr., 1984. Land mammals from the Calvert Formation, Pamunkey River, Virginia, *in* L. W. Ward and K. Krafft, eds. Stratigraphy and paleontology of the outcropping Tertiary beds in the Pamunkey River region, central Virginia Coastal Plain—Guidebook for Atlantic Coastal Plain Geological Association 1984 field trip. Atlantic Coastal Plain Geological Association, p. 236-239.

Woodburne, M. O., 1969. Systematics, biogeography, and evolution of *Cynorca* and *Dyseohyus* (Tayassuidae). Bulletin of the American Museum of Natural History 141:271-356.

Wright, D. B., 1998. Tayassuidae, *in* C. M. Janis, K. M. Scott, and L. J. Jacobs, eds. Evolution of Tertiary Mammals in North America. Cambridge University Press, Cambridge. p. 389-401.

Wright, D. B. & R. E. Eshelman, 1987. Miocene Tayassuidae (Mammaila) from the Chesapeake Group of the mid-Atlantic coast and their bearing on marine-nonmarine correlation. Journal of Paleontology 61(3):604-618.

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Parts published to date

1 On the taxonomy of the milliped genera *Pseudojulus* Bollman, 1887, and *Georgiulus*, gen. nov., of southeastern United States. Richard L. Hoffman. Pp. 1-19, figs. 1-22. 1992. $2.00

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